THE OPEN UNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2008/2009

CEX4230 – SOIL MECHANICS AND INTRODUCTION TO ROCK MECHANICS

Time allowed: Three Hours.

Date: Friday, 02nd April, 2009 Time: 9:30-12:30

PART A:
Answer all questions. All questions carry equal marks. Attach Part A of this paper to your answer script. You are advised to spend approximately One (1) hour for Part A. **Underline the correct response.** (36 points)

1. The equation $S = \frac{wG_s}{e}$ represents the phase relationship in an engineering soil. Which of the following statements are true?

   A) G_s is a dimensionless parameter.
   B) Parameter e always represents values between 0 and 1.
   C) S quantifies the fraction of water present in voids.
   D) Parameter w always represents values between 0 and 1.

   i) A and B ii) B and C iii) C and D iv) A and D v) A and C

2. A sieve analysis test performed on a particular soil gave the following results: Gravel 41%, Sand 55%, Fine-fraction 4%. It's group symbol most likely to be is:

   i) GW ii) SW iii) GP iv) SM v) SC

3. Which of the following statements are true?

   A) At Liquid Limit, soil consistency changes from liquid to plastic state.
   B) At Plastic Limit, soil consistency changes from Plastic to Solid state.
   C) If 13mm groove closure occurs at 28 blows, water content of the sample is more than its Liquid Limit.
   D) Liquid Limit of a soil varies with its natural moisture content.

   i) A only ii) B only iii) C only iv) D only v) A and C

4. Which of the following statements are true?

   A) The Plasticity Chart is used to classify soils when fine fraction exceeds 5%.
   B) The Plasticity Chart plots the variation of Plastic Limit with Liquid Limit.
   C) The A-line divides clayey soils from silty soils.
   D) Liquid Limit differentiates a `high plastic' clay from a `low plastic' clay.

   i) All of the above ii) A, B and C iii) A, B and D iv) B, C and D v) A, C and D

5. Which of the following statements are true?

   A) A soil that shows a rapid dilatancy reaction has a high clay content.
   B) Plasticity Test measures soil's ability to adsorb water to clay minerals.
   C) A high plastic soil has a high Dry Strength.
   D) A high plastic soil has a low Dry Strength.

   i) A and B ii) B and C iii) C and D iv) A and D v) B and D

6. 1-Dimensional Consolidation Test uses a dial gauge to measure soil settlement. The smallest division that is read is:

   i) 0.005mm ii) 0.002mm iii) 0.001mm iv) 0.01mm v) 0.02mm

7. A Constant Head Permeability Test performed on a fine-sand showed that Coefficient of Permeability, k varied linearly with e^3. A porosity of 0.32 gave a Coefficient of Permeability of 0.062 cm/s. The equivalent k for a porosity of 0.4 is:

   i) 0.176 cm/s ii) 0.181 cm/s iii) 0.185 cm/s iv) 0.22 cm/s v) 0.251 cm/s

8. A saturated soil element in a uniform soil stratum is located 5m below ground surface. The water table is at 1m below ground surface. Which of the following statements are true?

   A) The total stress in the soil element is hydro-static.
   B) The element is subjected to a vertical stress only.
   C) A pore water pressure of 39.2kPa acts on the soil element.
   D) Horizontal and vertical directions are considered as principal stress directions.

   i) A and B ii) B and C iii) C and D iv) A and D v) A and C

9. Which of the following statements are true? Coefficient of Consolidation ...

   A) Measures the rate at which excess pore water pressure dissipates from a soil.
   B) Measures the rate at which primary consolidation takes place.
   C) Estimates the total settlement during 1-D consolidation.
   D) Is less at higher overburden stresses.

   i) A, B and C ii) A, B and D iii) B, C and D iv) A, C and D v) A, B, C and D

10. Which of the following statements are true?

    A) Zero Air Void Curve relates soil moisture content to dry density of the soil.
    B) Points lying on this curve quantify the presence of all three phases: air, water and soil.
    C) Zero Air Void Curve depends on specific gravity of solids.
    D) The compaction curve intersects the Zero Air Void Curve at higher water contents.

    i) A and B ii) B and C iii) C and D iv) A and C v) All of the above

11. During visual classification test for coarse-grained soils, soils are grouped based on particle size. Fine-sands are considered to have particle sizes between:

    i) 0.002mm – 0.063mm
    ii) 0.063mm – 0.2mm
    iii) 0.2mm - 0.63mm
    iv) 0.063mm – 0.63mm
    v) 0.63mm – 2mm

12. An element of a sandy soil (with $\phi = 30^0$) is located at a depth of 2m below ground surface. If its unit weight is 16 kN/m^3. The active pressure on the soil element is:

    i) 9.8kPa ii) 10.3kPa iii) 10.7kPa iv) 16kPa v) 96kPa

13. Identify the correct relationship for the following three earth pressure coefficients:

    i) $K_a < K_0 < K_p$
    ii) $K_0 < K_a < K_p$
    iii) $K_p < K_0 < K_a$
    iv) $K_0 < K_p < K_a$
    v) $K_a < K_p < K_0$

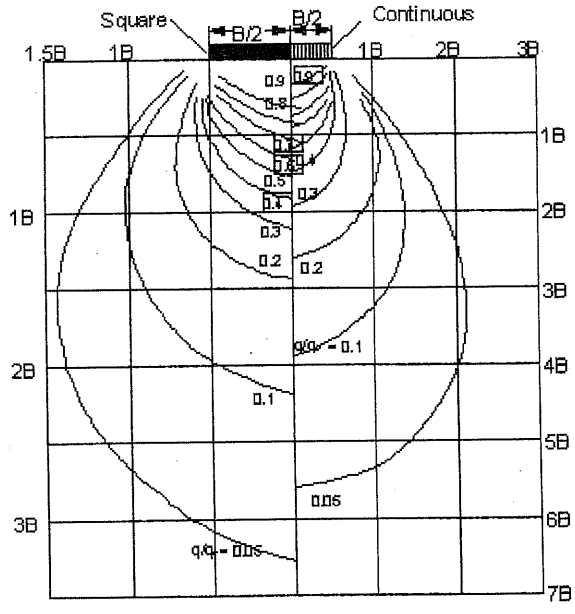
Questions 14 – 18: Please state your answer within the space provided.

14. Sketch the variation of deviatoric stress versus axial strain for a dense-sand, as observed during a conventional triaxial loading test. Name the axes. State the units of measurement.

15. Sketch the variation of size distribution versus particle size observed for a Clayey Silt (ML). Name the axes. Show principal values that explain your plot.

16. Sketch the variation of settlement δ versus $\sqrt{t}$ typically observed during a 1-D Consolidation Test performed on a low-plastic clay soil. Name the axes. Explain how you would determine the initial compression.

17. A pad-footing is subjected to a uniform pressure of 100kPa. Sketch the pressure variation with depth.



18. Sketch the variation of void ratio versus effective consolidation stress as observed during a 1-D Consolidation Test. Name the axes. State the units of measurement. Show compression and recompression segments.

PART B:

Answer four questions. All questions carry equal marks. You are advised to spend approximately 28 minutes per question. (16x4 = 64 points)

1. Figure Q1 shows the sub-surface profile of a particular site.
   a) State the principle of effective stress; explain or define the terms that you have used. (3 points)
   b) Sketch the variation of total vertical stress versus depth, indicating principal values at points A, B, C and D. (3 points)
   c) Sketch the variation of pore water pressure versus depth, indicating principal values at points A, B, C and D. (2 points)
   d) Sketch the variation of effective vertical stress versus depth, indicating principal values at points A, B, C and D. (2 points)
   e) Compute vertical stresses σ_v, σ'_v and horizontal stresses σ_h, σ'_h acting on a soil element located at Point E. (3 points)
   f) Sketch the Mohr's circles of stress with respect to total stress and effective stress for stresses computed in Q1(e) above. State principal values. (3 points)

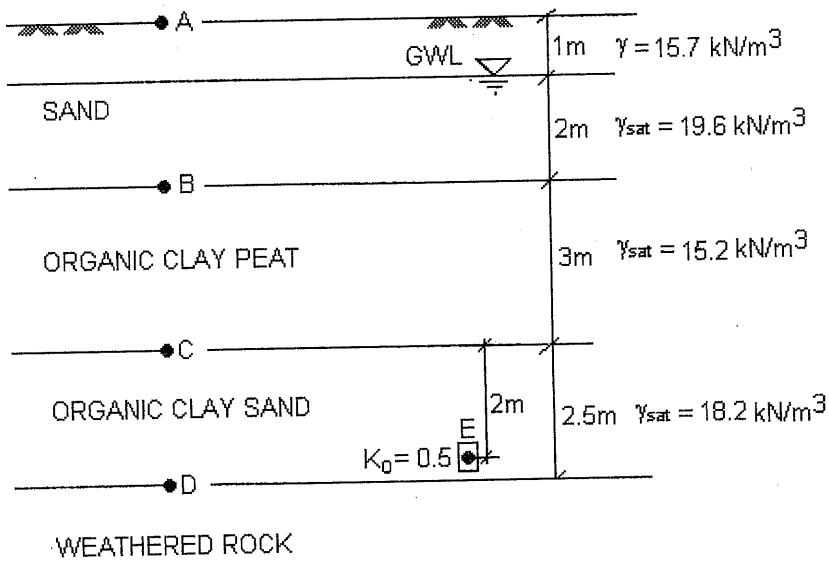


Figure Q1

2. You are expected to provide logical and sound reasons in support of your responses.
   a) Using a sketch of a particle size distribution curve explain why a Uniformly Graded Soil has a low Coefficient of Uniformity (e.g. $C_u = 2$) (4 points)
   b) Na-hexa-meta-phosphate is used as a dispersing agent, when performing the hydrometer test. Explain how gradation would change if a dispersing agent is not added. (4 points)
   c) The coefficient of consolidation is expressed as $c_v = \frac{T_v d^2}{t}$. We determine c_v experimentally, by considering time for 50% or 90% of primary consolidation. Explain why c_v reduces with effective consolidation stress, σ'_{v0}. (4 points)
   d) During Unconfined Compression (UC) test we applied the area correction $A = \frac{A_0}{1-\varepsilon_1}$; ε_1 being the axial strain. Explain the relevance of this correction when the specimen is stressed under undrained condition. (4 points)

3. A Consolidated Undrained (CU) triaxial loading test gave the following results:

Sample No.	Cell Pressure (kN/m^3)	Deviatoric Stress at failure (kN/m^3)	Excess Pore water Pressure at failure (kN/m^3)
1	250	170	109
2	500	320	250
3	700	455	350

a) Compute principal stresses σ_1, σ_3, σ'_1 and σ'_3 at failure. (4 points)

b) Plot Mohr's circles of stress at failure. Name the axes; show principal values. (3 points)

c) Compute c, ϕ, c′ and ϕ'. (3 points)

d) Suppose that you need to determine whether soil element 'A' (refer Figure Q3) is stable, given that stresses due to an imposed load of 50kPa are $\Delta\sigma'_v$ = 30kPa and $\Delta\sigma'_h$ = 20kPa.

i) Plot the two Mohr's Circles of effective stress corresponding to before and after loading situations. (4 points)

ii) State whether the suggested changes do not exceed the soil strength. (2 points)

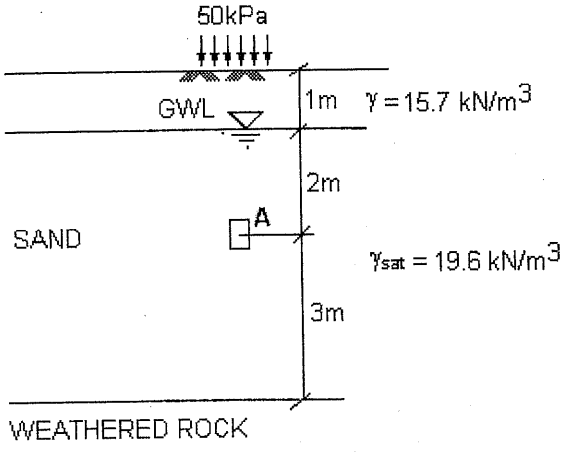


Figure Q3

4. Questions 4(a) to 4(d) require you to demonstrate your ability to interpret and apply information contained in figures and charts shown below.

a) Figure 4(a) shows a design chart used when designing a shallow foundation. Discuss the purpose of this chart; state its limitations; explain the parameters used; identify dependent and independent variables. (4 points)

b) Figure 4(b) shows the variation of active and passive earth pressures, with depth. Explain the parameters shown in this figure. Compare the two cases shown by lines a – a and p – p. (4 points)

c) Figure 4(c) shows the variation of void ratio versus effective consolidation stress. Explain how you would compute m_v. (4 points)

d) Figure 4(d) shows the variation of dry density with water content for various soils types. Explain the observed trends. (4 points)

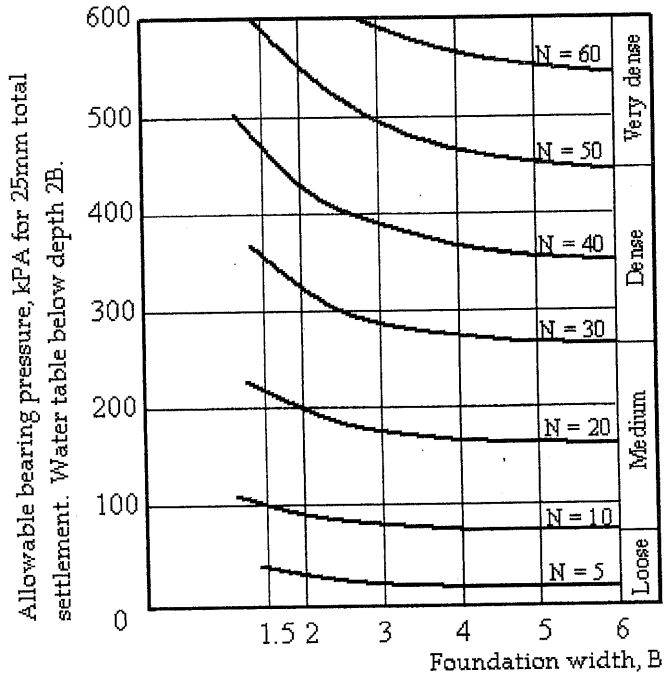


Figure 4(a)

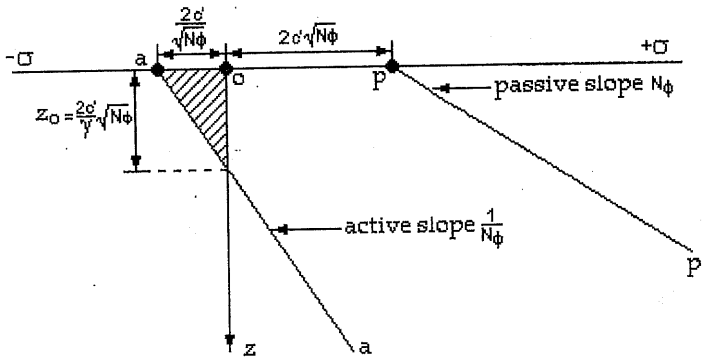


Figure 4(b)

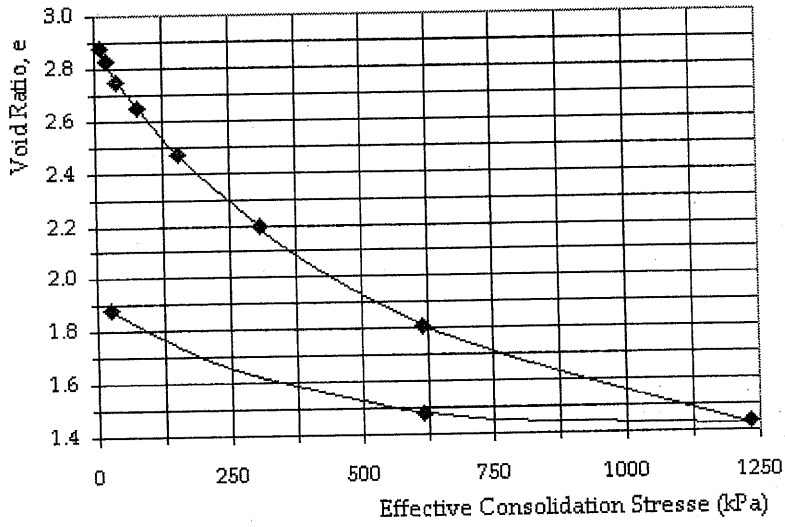


Figure 4(c)

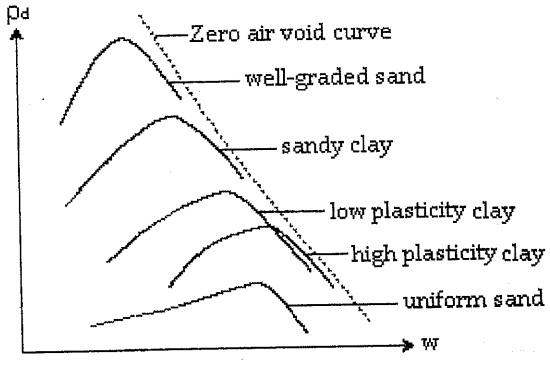


Figure 4(d)

5. The phases of the 3 – phase soil model are expressed in terms of parameters that represent mass and volume quantities.

   a) Define G_s, S, e, ρ and ρ_w in terms of these parameters. (5 points)

   b) Using the definitions you have derived in 4(a), show that bulk density, $\rho = \left[\frac{G + Se}{1 + e}\right]\rho_w$. (4 points)

   c) A sand deposit 5m thick overlies a clay stratum. The groundwater table is located 2m below the ground surface. The sand stratum above the groundwater table has a degree of saturation of 45%. Void ratio across the sand stratum is found to be uniform, and equal to 0.62. G_s = 2.65.

      i) Compute the bulk unit weight for the sand stratum. (2 points)

      ii) Compute the corresponding saturated unit weight for the sand stratum. (4 points)

      iii) Compute the submerged unit weight for the sand stratum. (1 point)

6. Figure Q6 shows a filtration unit of an industrial rainwater collection system. The system maintains a constant water height of 1m in the upper tank and allows water to flow under gravity to an underground sump. The designer wishes to have a 2m high column of uniformly graded fine-sand, in the 100mm internal diameter down pipe (i.e. section BC).

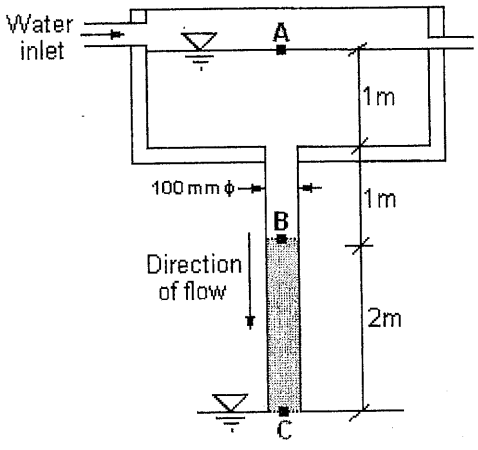


Figure Q6

a) Compute the pressure head, elevation head and total head at points A, B and C. (6 points)

b) Hazen (1930) proposed the following empirical relationship $k = CD_{10}^2$ cm/s. C is a constant varying between 0.4 – 1.2. Estimate a suitable coefficient of permeability for fine-sand. (3 points)

c) Compute the expected flow rate in litres/min. (5 points)

d) During extended use, the sand-filter may get clogged with finer particles, hence may result in a reduced flow rate. Discuss whether this would affect the hydraulic gradient across the sand filter. (2 points)

7.

a) Figure Q7 shows a deep circular foundation carrying a 650kN structural load. D_f = 15m; f_s = 15kPa; diameter = 450mm.

i) Compute the carrying capacity in skin friction. (4 points)

ii) Assuming a factor of safety of 2.0 for skin friction and a factor of safety of 3.0 for end bearing, compute the required ultimate end bearing capacity. (4 points)

b) Define Rock Quality Designation. Explain its relevance to bearing strength of rock. (4 points)

c) Explain how bed-rock quality is investigated. (4 points)

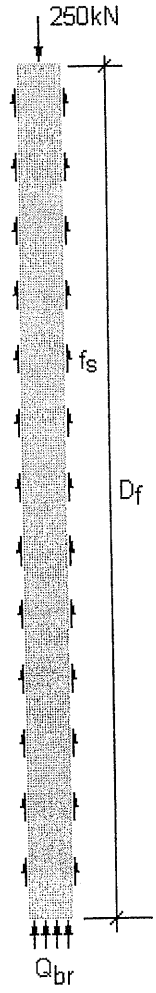


Figure Q7